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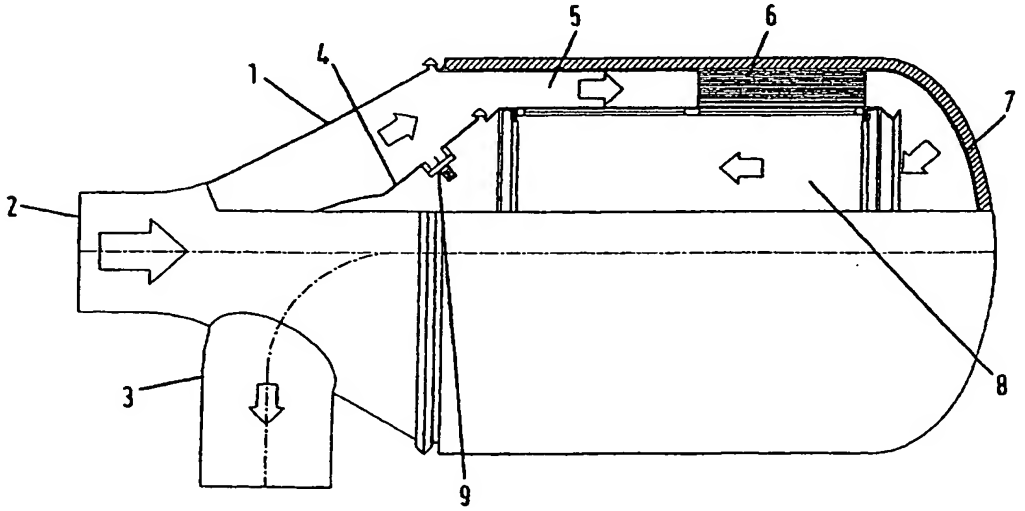
(54) Title: DEVICE AND METHOD FOR REMOVING SOOTY PARTICULATE FROM EXHAUST GASES FROM COMBUSTION PROCESSES



(57) Abstract: A canister (1) contains a catalyst for generating NO_2 and a filter (8) for trapping PM, e.g. from diesel engines. The filter is thermally isolated from the canister, and preferably is surrounded by an annular monolith comprising the NO oxidation catalyst or a SCR catalyst. The invention facilitates the combustion of PM even at low exhaust gas temperatures, in a compact device.

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IMPROVEMENTS IN POLLUTION CONTROL

This invention concerns improvements in pollution control, and more especially it concerns an improved device and method for removing sooty particulate "PM" from exhaust gases from combustion processes, particularly from diesel engines.

The leading technology for removing PM from heavy duty diesel engine exhausts is believed to be Johnson Matthey's "Continuous Regenerating Technology" or "CRT™". This is described broadly in USP 4,902,487 and utilises the fact that PM may be combusted at significantly lower temperatures in reactions with NO_2 than the conventional reaction with oxygen. The commercial CRT™ devices pass the exhaust gas through a catalyst which is effective to convert NO into NO_2, traps PM on a downstream filter and allows the NO_2 to combust the PM. The CRT™ device is being fitted to many thousands of heavy duty trucks and buses in advance of the regulations being introduced in Europe and U.S.A. A characteristic of light duty diesel engines, however, is their exhaust gas temperature is appreciably lower than that of heavy duty diesel engines. A number of engine design modifications introduced for both fuel efficiency and pollution control reasons, and the use of small turbocharged diesel engines, have reduced the exhaust gas temperatures (and NO or NO_2) levels to the point where even the CRT™ does not produce sufficient NO_2 and/or the reaction proceeds efficiently only under certain operating conditions when the exhaust gas temperature rises. Competing technology such as the catalysed PM trap is, we believe, even less able to cope with such engine exhaust gases and such exhaust gas temperatures, and these tend to clog up quickly.

We now provide an improved CRT™ design believed to be especially suitable for light duty diesel engine exhausts, and all other diesel engine exhausts where the temperature is rather low for effective performance of the various oxidation/combustion reactions. Accordingly, a device for the continuous or part-continuous removal of PM from exhaust gases from the combustion processes, comprise a canister, said canister containing a catalytic element capable of converting NO in the exhaust gases to NO_2 and a trap for said PM, characterised in that the trap is mounted such that it is thermally isolated from the canister and preferably is in good thermal contact with the catalyst.

A preferred layout is to use an annular catalyst surrounding the filter. Suitably this can be the NO oxidation catalyst or another catalyst.

The invention further provides an improved method for the continuous or part-continuous combustion of PM in combustion exhaust gases by trapping said PM and combusting the trapped PM using NO_2, characterised in that the temperature of the filter is maintained at an effective temperature by isolating the filter from the external environment.

The presently preferred method of constructing the device according to the invention is to use an annular catalyst, surrounding the PM trap. Without wishing to be bound by any theory, it is believed that such an arrangement is advantageous because the PM trap is isolated from the canister, so that the trap is not cooled by ambient air, and generally, the filter temperature is thus maintained at a higher temperature, enabling PM combustion to take place even at lower exhaust gas temperatures.

In one embodiment of the invention the annular catalyst is the catalyst for the oxidation of NO to NO_2. The exhaust gases pass over the annular catalyst and then the gas stream must be reversed in order to cause it to flow countercurrent through the trap. This arrangement brings several advantages:

1. The section of the trap which is most used for both trapping and combustion is facing towards the hot exhaust gas stream, thus helping to maintain the filter temperature;
2. The catalyst itself will be cooled by contact with the canister, which has the result that NO_2 production is lowered during low exhaust gas temperatures, at which the NO_2-PM burning reaction is slow, and reducing the opportunity for NO_2 to slip through the device unreacted; and
3. To some extent the exotherm from the NO oxidation reaction heats the trap, thus increasing the combustion reaction.

In another embodiment of the invention, the device incorporates a Selective Catalytic Reduction ("SCR") zone. SCR is used to remove NO_2 from the exhaust gas before the gas is released to the atmosphere. A reductant such as ammonia, hydrazine, urea or lower alkylamines is injected upstream of a catalyst that promotes the selective

reduction of NO_2. Desirably, the SCR catalyst is annular and is placed around the filter. In such an arrangement, the oxidation catalyst may be in an axial position with regard to the filter. The combination of SCR with an oxidation catalyst and filter is covered in general terms in our pending patent application No. PCT/GB99/00292, but is described therein in an essentially linear disposition. This embodiment of the present invention is believed to offer particular benefits, in that both the filter and the oxidation catalyst are surrounded by a hot zone or warm exhaust flow at all times, thus ensuring the most advantageous utilisation of exhaust gas heat for the required reactions. The exothermic SCR reaction provides additional heat to the filter. Also, the entire unit can be constructed in a very compact form, suitable for on-board vehicle use.

The preferred device according to the invention can be readily constructed, using conventional mechanical engineering and construction techniques. If desired, substantially all, or a desired portion, of the canister may be insulated to maintain reaction temperatures as high as possible.

The device according to the invention may be combined with an Exhaust Gas Recirculation system, in which the gas for recirculation is taken downstream of the device, or possibly downstream of the catalyst.

The device of the invention may be fitted with a by-pass or pressure-relief means, to permit exhaust gases to flow even if unusual operating conditions caused complete blocking of the trap.

The catalyst used in the invention is preferably a high-loading Pt containing catalyst, e.g. containing 10 to 150 g Pt per cu ft (353-5297g Pt per m^3) of catalyst volume. Other catalytic components or promoters may be present. The catalyst is preferably deposited on an annular honeycomb monolith which may be metal or ceramic and is of generally known type. The trap may also be of generally known type, but is preferably a ceramic wall flow filter. It may be mounted within the device by a quick-release clamp, to permit the trap to be reversed and/or cleaned to remove accumulated ash.

In a further embodiment of the invention, a single ceramic monolith may be used both as the oxidation catalyst support and as the trap. In such a case, exhaust gases are fed to the outermost cells of the monolith, which are catalysed, then the gases are forced to flow through the central portion which has alternating cells at each end blocked, so that the central portion acts as a wall flow filter.

It will be understood that the terminology "trap" and "filter" includes any apparatus causing the PM to be retained or have a sufficiently lengthy residence time that reaction with NO_2 takes place.

The canister used in the invention may be manufactured from stainless steel, and may be insulated in part or in whole. Preferably, the device is used with an engine fuelled with low-sulphur diesel fuel, preferably less than 50ppm S, more preferably less than 10ppm S.

The invention will now be described by way of example only, with reference to the accompanying drawings, and figures, in which:

Fig 1 is a schematic drawing, partly in section, of a first embodiment of the invention,

Fig 2 is a schematic drawing, partly in section, of a second embodiment of the invention,

Fig 3 is a schematic drawing, partly in section, of a third embodiment of the invention, incorporating SCR,

Fig 4 is a graph showing the temperature distribution in a CRT™ reference system

Fig 5 is a graph showing the temperature distribution in the first embodiment of the invention as represented schematically by Fig 1, and

Fig 6 is a graph showing the temperature distribution in the second embodiment of the invention as represented schematically by Fig 2.

In the drawings and the following description, identical reference numerals are used for identical parts.

Referring to Fig 1, a stainless steel canister, 1, is provided with an inlet, 2, for diesel engine exhaust gases, and an outlet, 3, for gases having passed through the device of the invention. The inlet and outlet positions are not significant, e.g. the inlet may be radial and the outlet axial, or both inlet and outlet may be radial, providing that the gas

flow through the device is in the correct order. The incoming exhaust gases are diverted by a metal cone, 4, to pass through an annular space, 5, and an annular catalyst, 6, supported on a flow-through honeycomb support. The NO content of the exhaust gases is converted at least in part to NO_2 in the catalyst; other reactions may also take place on the catalyst or, if desired, on a pre-catalyst. The gases, enriched with NO_2, are turned by the rounded end, 7, of the canister, to flow through a central PM trap, 8, before entering the cone 4 and being carried out through outlet 3. In Fig 1, the canister is partly insulated to retain reaction heat. A simple poppet-type by-pass valve, 9, permits a relief of excessive pressure if there is blockage of the filter.

Referring now to Fig 2, a single ceramic substrate, 10, has a peripheral annular portion, 10a, with flow-through cells and a central portion, 10b, with alternately plugged cells. The annular portion 10a is suitably coated with washcoat and with platinum catalyst, and is effective to convert NO in the gases to NO_2. The central portion of the monolith has alternate cells plugged, so that it acts as wall flow filter.

Referring now to Fig 3, the entire outer canister 1 is insulated, and contains a platinum oxidation catalyst, 6, supported on a ceramic flow-through monolith, and a ceramic wall-flow filter element or trap, 8, held in axial relationship within a central canister part, 30. The part 30 is fitted with a conical end, 31, fitted with mixer vanes, 32. An injector for SCR reductant fluid , 33, is fitted to inject a suitable fluid reductant into the rapidly rotating gas flow, before the mixture is reversed in direction and flows through an annular SCR catalyst, 34. A final section of catalyst, 35, is provided to clean up the exhaust flow, eg to remove ammonia.

This embodiment offers good mixing of gases with reductant whilst maintaining the high filter temperatures characteristic of the present invention. Particularly good conversions of both PM and NOx pollutants can be obtained in a very compact unit. The other features mentioned above, such as easy removal/cleaning/reversal of the trap, and the incorporation of a by-pass valve, may also be included in this embodiment.

Figures 4-6 represent data collected to demonstrate the thermal management benefits of the first and second embodiments of the invention as represented in Fig 1 and Fig 2. A reference CRT™ system (in which the filter is not thermally isolated from the

canister) and the two embodiments of the invention were subjected to transient conditions, during which the temperature into the filter system changed substantially. The response of the temperature at different positions in the filter system was monitored using thermocouples. In each case the thermocouples were located in the following positions:

(a) between the catalyst and the filter,

(b) along the central axis of the filter, half-way along its length ('Centre Middle'),

(c) at the outside edge of the filter, half-way along its length ('Edge Middle'),

(d) along the central axis of the filter, at the filter outlet ('Centre Back'),

(e) at the outside edge of the filter, at the filter outlet ('Edge Back').

Figures 4-6 show how the temperature at these points varied as the inlet temperature to the system was changed.

Fig 4 shows that the temperature along the central axis of the filter closely follows the temperature between the catalyst and the filter (ie the temperature at the filter inlet). However, the temperature is significantly lower at the edge of the filter (ie where there is contact with the can). By contrast, Figs 5 and 6 show that in the embodiments of the present invention the temperature distribution is far more uniform across the filter. There is no significant cooling at the edge of the filter, showing that the filter temperature is maintained at a higher temperature, thus enabling the soot combustion reaction.

CLAIMS

1. A device for the continuous or part-continuous removal of PM from exhaust gases from combustion processes, comprises a canister, said canister containing a catalytic element capable of converting NO in the exhaust gases to NO_2 and a trap for said PM, characterised in that the trap is mounted such that it is thermally isolated from the canister.

2. A device according to claim 1, wherein the trap is in good thermal contact with the NO oxidation catalyst or another catalyst, whereby it may gain heat from such catalyst in operation.

3. A device according to claim 1 or 2, wherein an annular catalyst surrounds the filter.

4. A device according to claim 3 wherein the annular catalyst is the NO oxidation catalyst.

5. A device according to any of the preceding claims, comprising also means for injecting a SCR reductant and a SCR catalyst.

6. A device according to claim 5 wherein the SCR catalyst is an annular catalyst surrounding the filter.

7. A device according to any one of the preceding claims, wherein the catalyst and trap form part of a unitary monolith.

8. A method for the continuous or part-continuous combustion of PM in combustion exhaust gases by trapping said PM and combusting said trapped PM using NO_2, characterised in that the temperature of the filter is maintained at an effective temperature by isolating the filter from the external environment.

9. A method according to claim 8, wherein the exotherm from a catalytic process is used to provide heat to the filter to maintain its temperature at an effective level for the combustion of PM.

10. A method according to claim 8 or 9, wherein the cleaned gases leaving the filter are subjected to a SCR process.

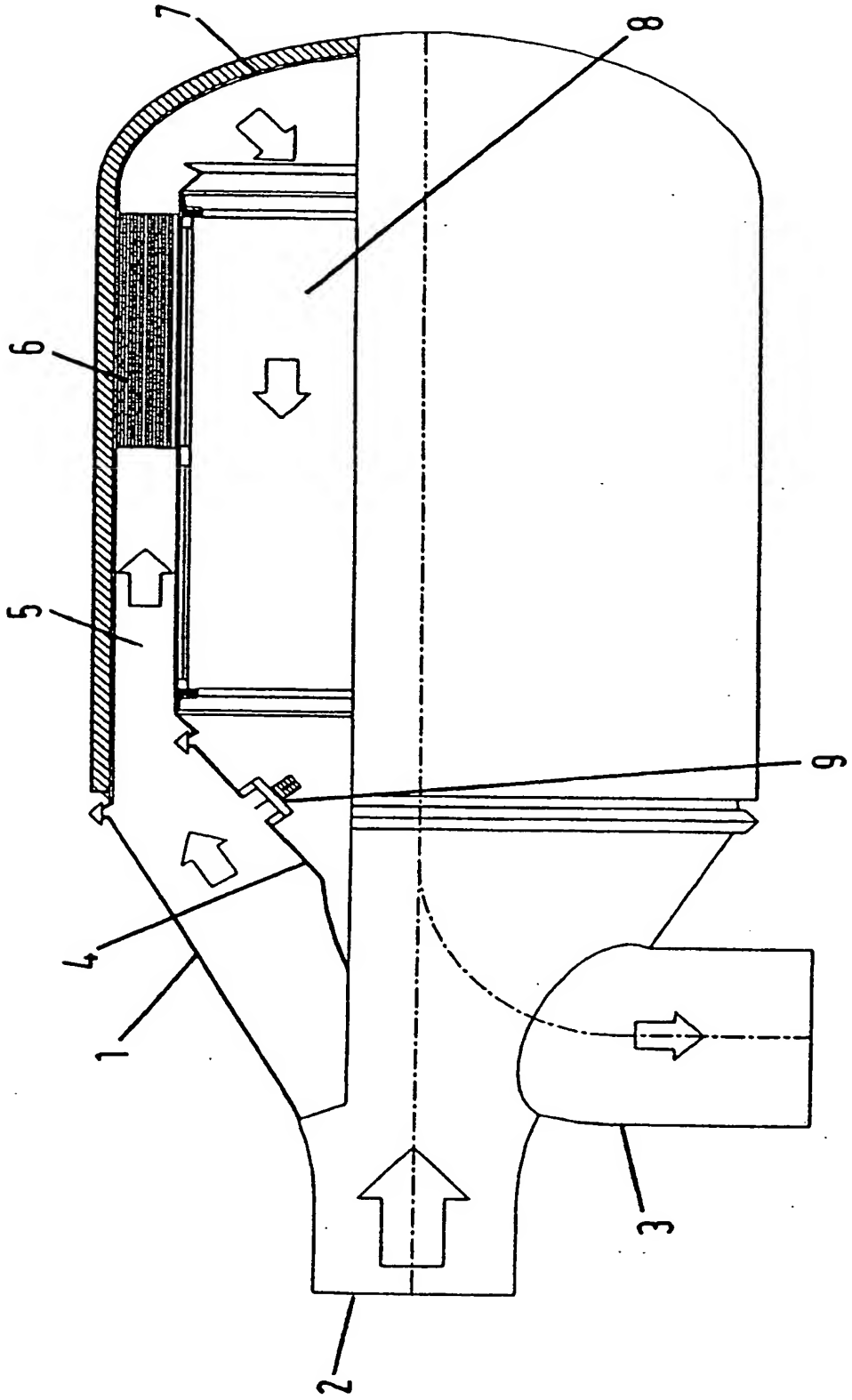


FIG.1

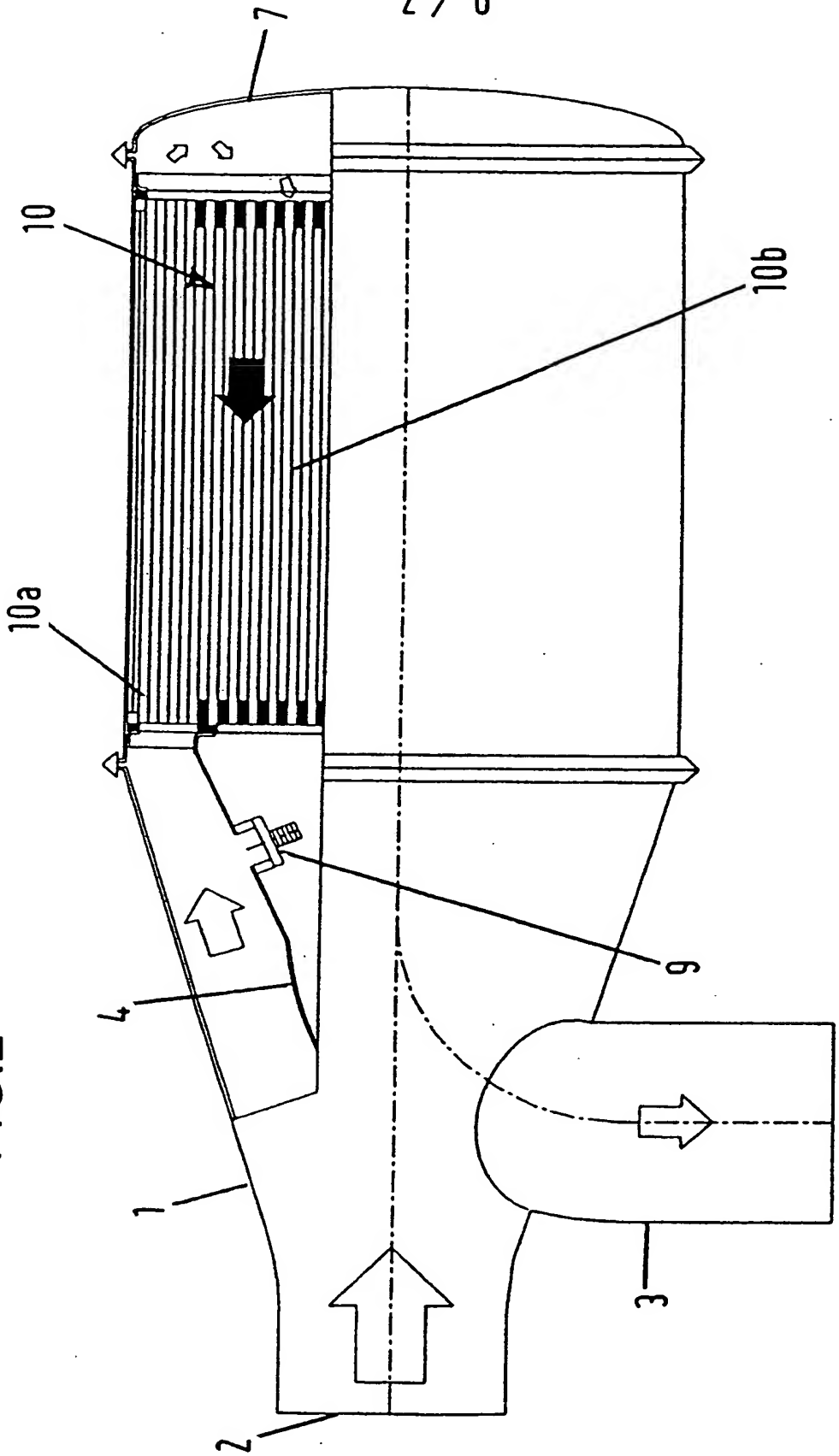


FIG.2

FIG.3

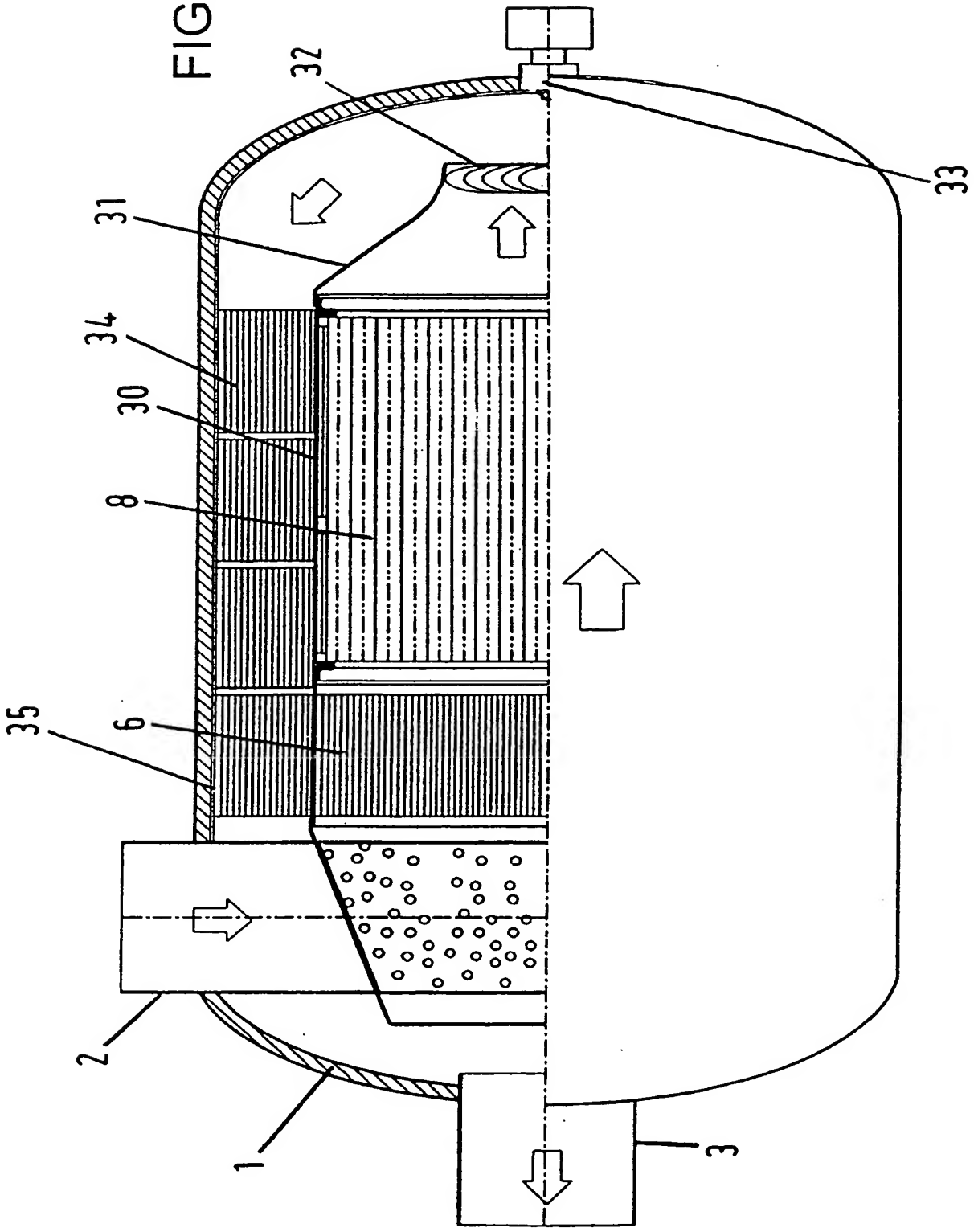
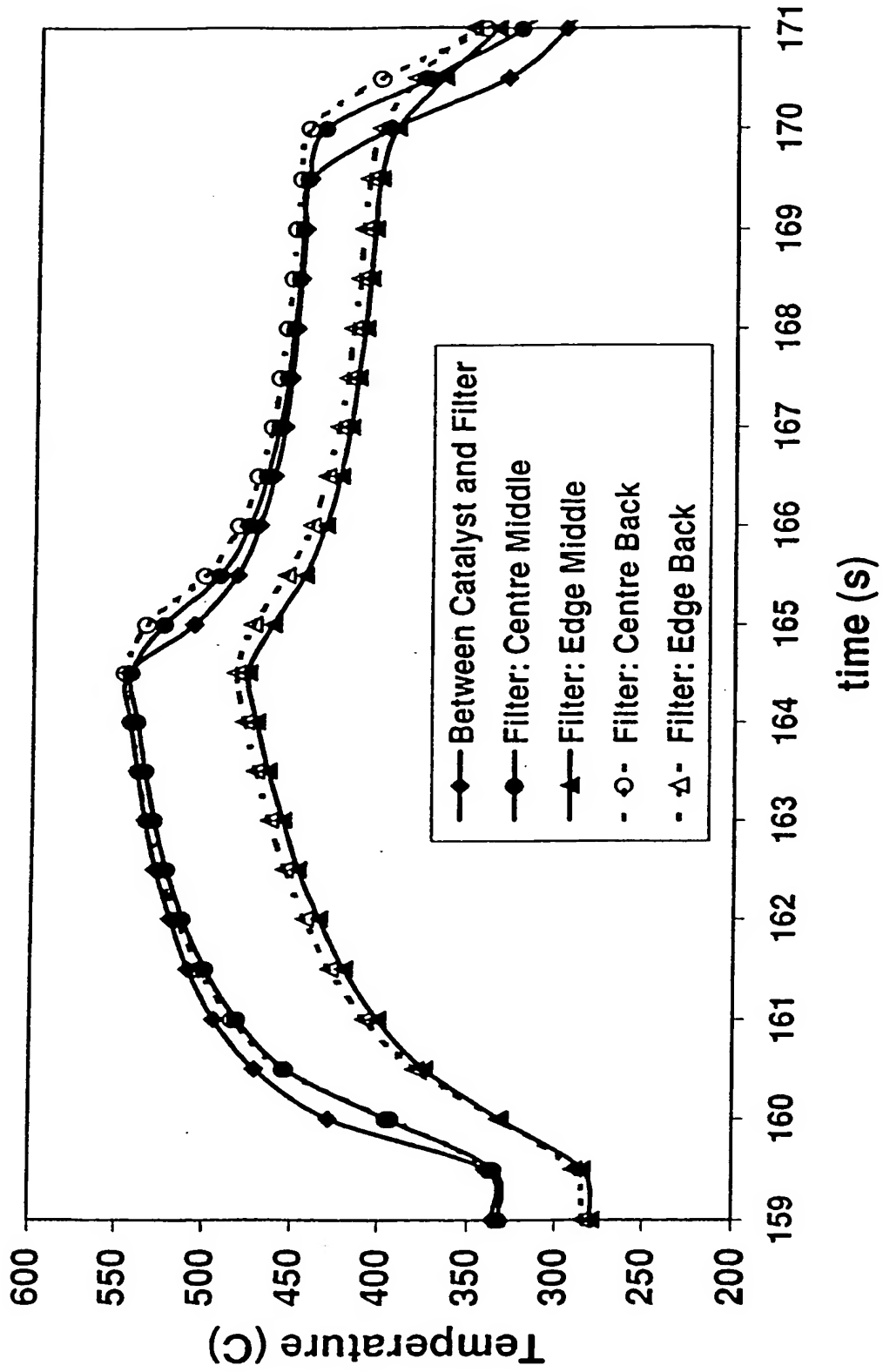


FIG.4

CRT Reference



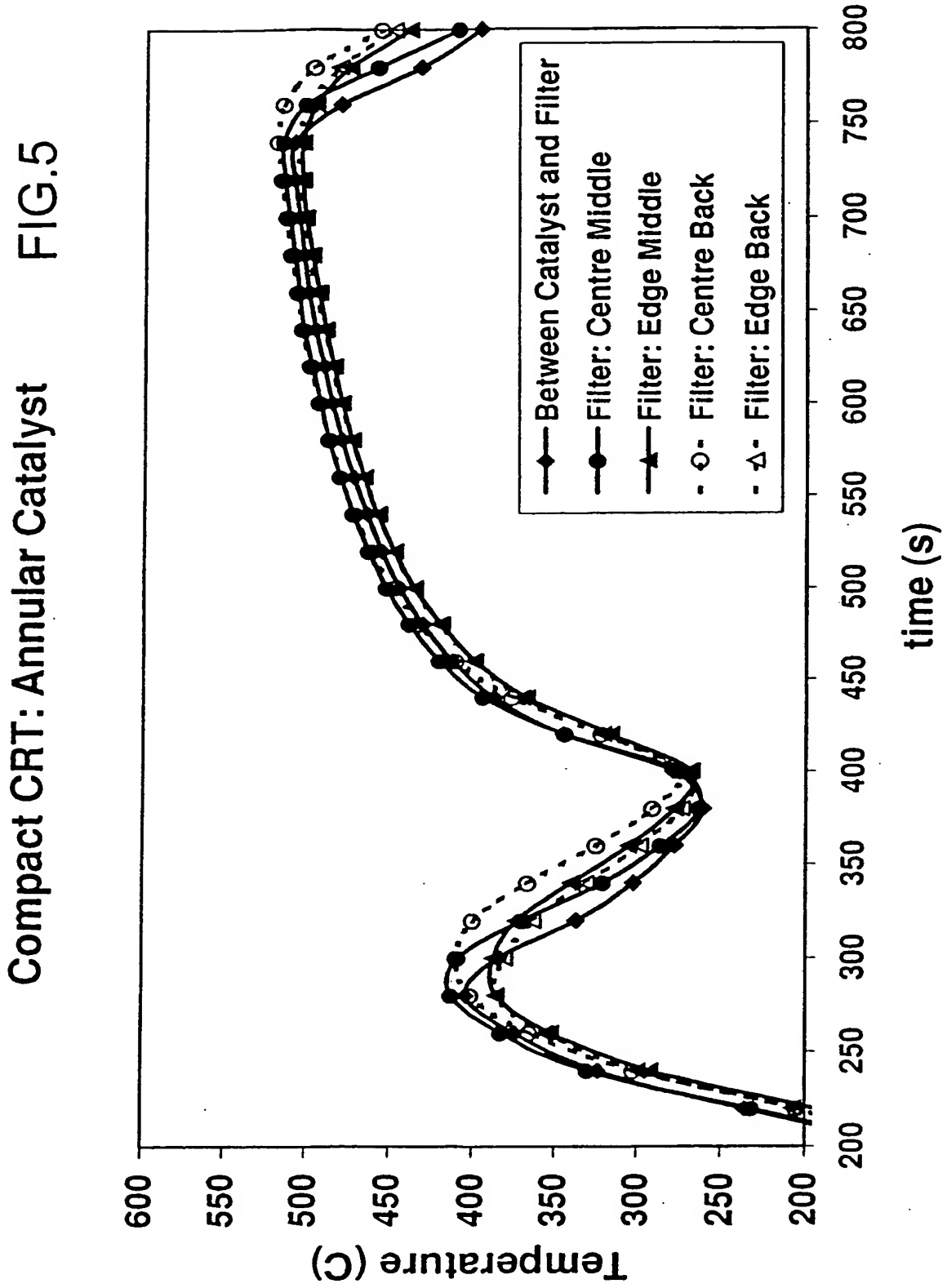
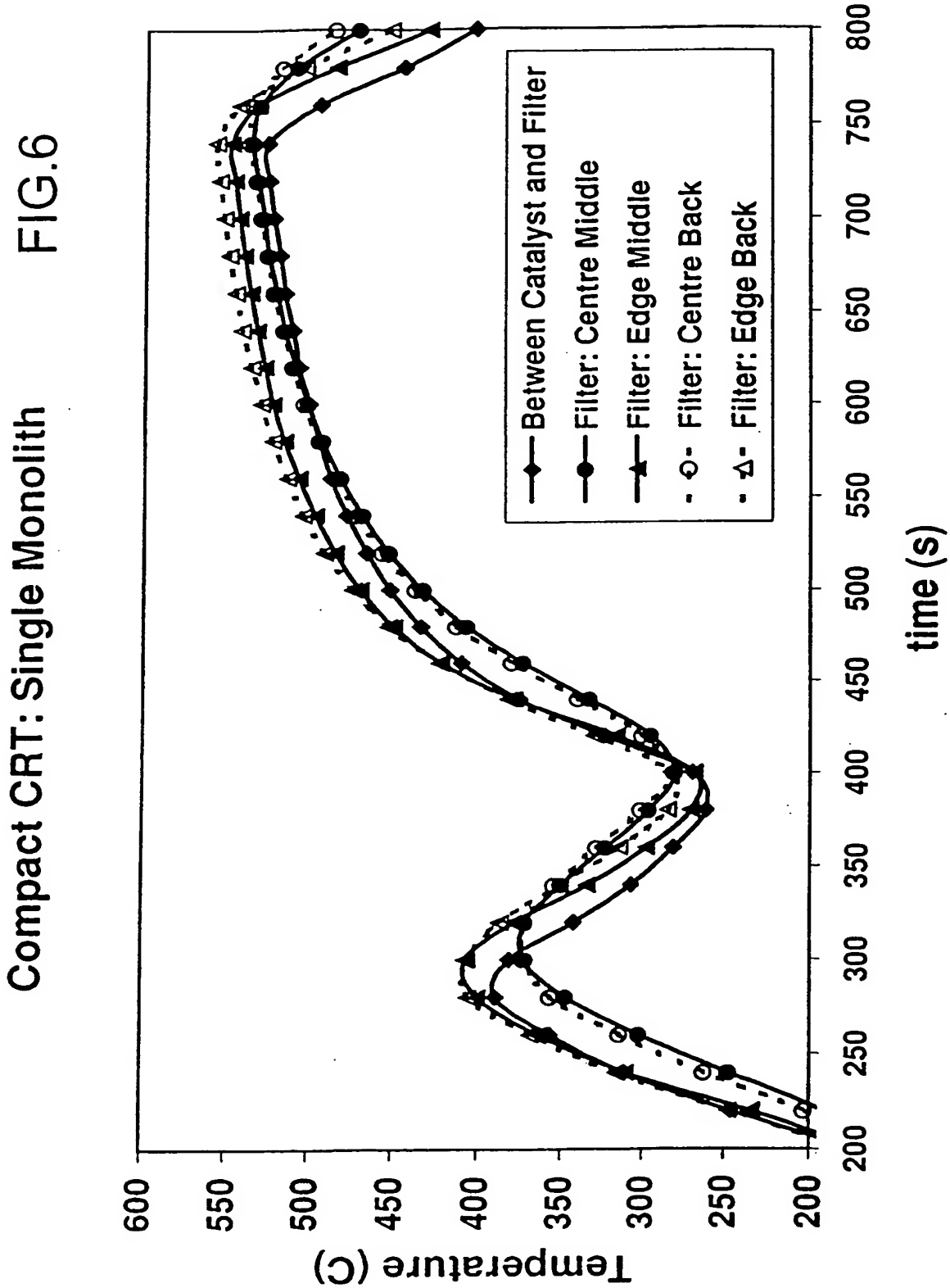


FIG.5

FIG.6



INTERNATIONAL SEARCH REPORT

Interna)l Application No
PCT/GB 00/02342

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F01N3/021 F01N3/035 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 99 44725 A (JOHNSON MATTHEY PLC ;CHANDLER GUY RICHARD (GB); TWIGG MARTYN VINCE) 10 September 1999 (1999-09-10) abstract; figures 1,3,4	1,8
Y	US 4 902 487 A (JUNG HYUN J ET AL) 20 February 1990 (1990-02-20) cited in the application the whole document	1,8
Y	EP 0 319 299 A (MINNESOTA MINING & MFG) 7 June 1989 (1989-06-07) claim 6; figure 1	1,8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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